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GROUP

CANADIAN PATENT

LINER EXPANDER

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Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

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PRIORITY DATE

U.S.A.

No. OF CLAIMS

LINER EXPANDER

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This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing . or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

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Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

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Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

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Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the wall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 23 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential sorew element 39 which transmits the losding on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 35 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38a, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

Constant force spring element 37 comprises column element 43, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

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The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft lo.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein Pc is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A end B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

epproximately one inch, at which the longitudinal deflection was approximately:
0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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I CLAIM:

- 1 1. A device for expanding a metallic liner inside a conduit which 2 device comprises a shaft element, an expanding die member attached to said 3 shaft element, said die member comprising a movable liner-forming member positioned on said shaft and being radially movable in respect thereof to contact said liner, an expander member slidably positioned on said shaft 5 6 between said shaft and said die member to move said liner-forming member from said shaft, and a constant force spring member positioned on said shaft 7 8 to contact said expander member and to maintain said expander member against 9 said liner-forming member, whereby said liner-forming member is urged against 10 said liner by a substantially constant force.
- 1 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said 2 conduit to expand said liner: a cylindrical shaft element, an expanding die 3 member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable outwardly therefrom to contact said liner, a cone member slidably positioned on said shaft between 6 said shaft and said arm members to urge said arm members outwardly from said 8 shaft, and a constant force spring member positioned on said shaft to contact said cone member and to maintain said cone member in contact with said arm 9 members, whereby said arm members are urged outwardly by a substantially 10 11 constant force.
- 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

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- 4. The device of Claim 3 wherein said compression means comprises
 2 a differential screw connecting said spring member and said shaft.
 5. The device of Claim 3 wherein said stop means comprises a
 2 sleeve-like element connected to said movable bearing plate member and
 3 slidably positioned on said shaft and a member connected to said shaft to
- 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said shaft.

limit the travel of said sleeve-like element.

3 wider face normal to the diameter of said shaft. 1 7. A device for installing an expanded metallic liner in a conduit 2 which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed 3 circumferentially around the outside of said shaft and being pivotable out-5 wardly therefrom to contact the liner; a conical expanding member slidably 6 positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft; a plurality of slender columns, each . 7 8 having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lower bearing plate member, each slidably positioned on said shaft and contacting opposite ends of said 10 columns; limiting sleeves attached to each of said bearing plate members 11 and slidably positioned on said shaft; a shoulder member on said shaft; a 12 differential screw element connecting said shoulder and said shaft to apply 13 a buckling load to said columns; said shoulder being engageable with the 14 limiting sleeve connected to said lower bearing plate member, whereby the 15 axial travel of said bearing plate members is limited; said column members 16 . 17 transmitting their buckling load to said arm members to urge said arm members outwardly with a substantially constant force. 18

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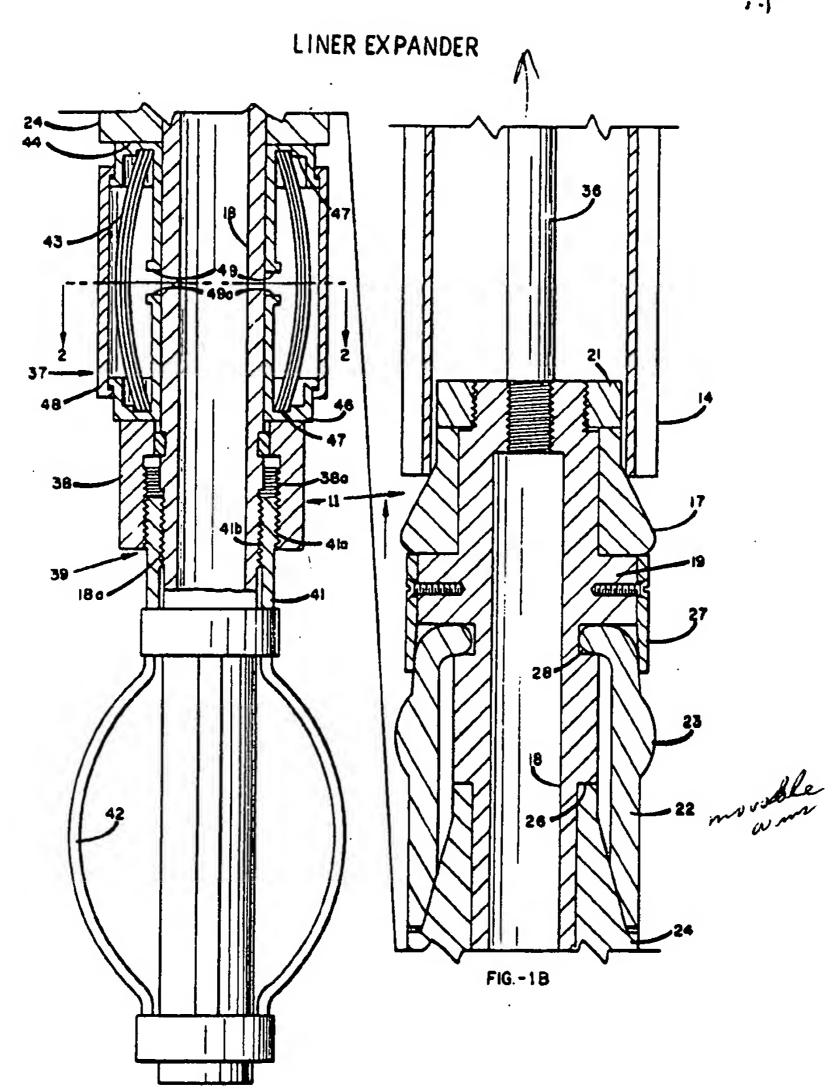
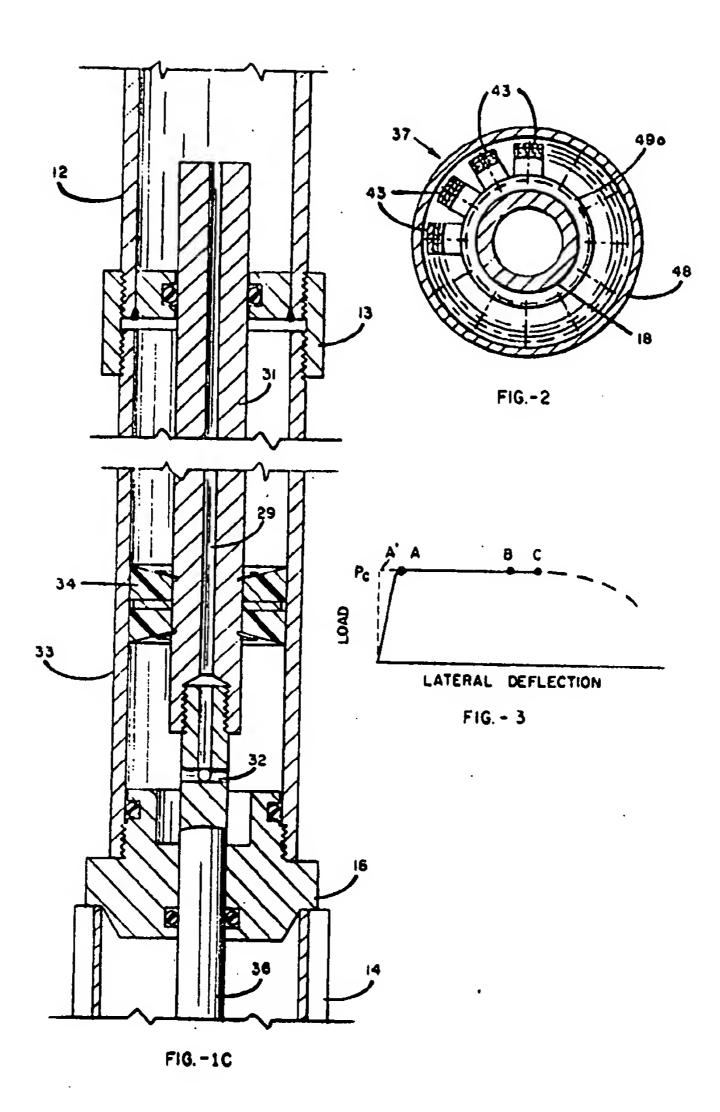


FIG.-1A



Sorry, the requested images for patent number 736288 are unavailable.

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3. The ferios of Claim & standa said scanters force spring accept comprises a plantity of others disposed around said shaft, a first boaring plate number and a second bearing plate scatter, each of said boaring plate members combacting opposite code of said columns, at least one of said tearing plate numbers being novebly positioned on said shaft and being in contact while said come number, stop means commerted to said start to limit the angal traval of said members plate number along said start, and compression means for emintaining a lateral deplection in said columns.

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- . A. The device of Claim 3 wherein said outpression grows comprises a differential surset equacting said appring sander and said shaft.
- 5. The device of Chain 3 wherein sold stop means comprises a alseve-like element commented to said moveble bearing plats number and children's positioned on said short out a scottor concentred to said shart to limit the transit of said slaves-like element.
- 6. The device of their 3 whereis soil columns have a sectingular moss-species, the width being greater than the thickness, and having the wider face swood to the dissolute of said shaft.
- 7. A device for installing at expended motallis liner to a comissis which comprises a sylindrical shaft classifi; so according the against normal on mid shaft, said the senter comprising a plantity of are senters disposed directorentially around the outside of eald shaft and being pleotable netmaily therefrom to contact the liner; a scaled arguming mater alidably positioned on said sheft between said shaft and maid are ecology to upps said are numbers outstandly from said shelt; a plurelity of slander columns, cash baving a long reutingular cases-sevilon and disposed sire.extendedly shout suld chaft; an upper bouring plate member and a lower tearing plate suffer, such slightly positioned on said short and outdooting opposite onds of mad enluser; limiting eleaves ubtended to each of said bearing plate members and alidably positioned an said whally a shoulder number on said shally a differential acres showed connecting exit shoulder and said shorts to apply a landiting load to said enimus; said thouless being consensate with the limiting siesve momented to each laster bearing plate mester, wherety the arial travel of said bearing plate members in limited; said column vembers branesitting their buckling look to said arm numbers to urgs said arm spacers ortantly with a substantially courtent force.

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Piggree 34, 18 and 10, taken together, constitute a partial sees tional view of a preferred embediement of a liner expending took according to the present invention; and

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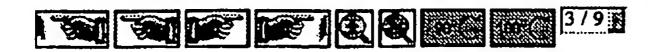


Figure 2 to a sestional view of the apparatus of Figure 1A taken at line 2-2; and

Figure) is a typical plot of applied lock versus befinction for the constant force spring device of the Lawrention.

Referring to the drawings, Figure 11 is the button portion of a liner expending tool for one is installing a motallic liner to a well, while Pigure 13 Libertrates We middle section of such a tool and Pigure 10 represents the upper sestion of the tool. The expending tool il is ablashed to stantoni well taking 15 by ampling 15 and, typically, may be lovered from the 10 surface through a well ensing (not shown) to a point in the swring at which it is desired to invial a metallic liner. Defore inserting the tool into the well, an alongsted vertically corrugated liner IP fabricated from mild steel, or other suitable mileshie natorial, is placed on the tool. The corregated liner is occurred in position by contact at its upper end with a cylindrical shoulder marker 16 and, at the lower and by content with a first-stage expansiing die 17 in the form of a tromosted circular come which serves as a firststudy expending die in the surmer barainsfier described. The expending die is fixedly ablanted to a centrally located, elemented epidedrical bollow shaft 18 which forms a portion of the lody of the tool. As shown, the expending sie 17 20 is held in place between a lower shoulder 19 and coller 21 threaded onto the shert. . A plurality or movehile arms 89, preserably provided with outswelly sularged portions 45 mear the top; are disposed in the form of a sylinker around that's 16. The enlarged purtions of the arms 23 squa being moved outvarily excitest the liner to gurfous the final step of expending the corregated ... liner into a substantially splintrical shape. The are senters IT are justally ettected to the staff so as to be movehle outwardly from the shaft by a tapered expending member 26 alidably postationed on the sheft to serve as a second-stage expender. The series of the moster Sh, as shown, moves appearily along the 30 inside surfaces of the area 22 and the outside earlies of caparding member 25

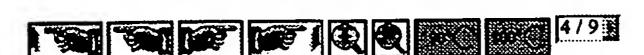




notil it contants shoulder 25 provided on the rheft. As member 24 moves in a documently direction arms 22 feld invertily toward the shaft. The expending arms 22 are held to place as the shaft by collect 27 and circular grooms 20 provided on the shaft.

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forces between the tool and the liner and the presence emerted against the ensing are maintained at predatoralized safe levels. The constant force spring manhor ensures that the southest presence between the liner feming portion 25 of the sons 22 is great enough to provide the desired deformation of the one-ing, while preventing demand to the sensing or to the tool.

The speakert force spring sucher 37 is aligned, sounted on the about 18 and held between the expending stanget 26 and a cylindrical lower chouldes master 30 forming a portion of a differential error element 39 which transmits the looking on spring sember 37 to shart member 18. The differential court 10 almost comprises shaft matter 15 on the outrids of value are out sale threads 10s, the lover shoulder master 30 provided with female threads 30s and thinkle member \$1, provided with threads \$1s and \$1b on the origins and the inside, respectively, to segue with threads on the shaft and the shoulder. The two sets of threads are sourse, such as square, modified square, or Acom threads, to withstand very high loads and differ in pitch so that shoulder 35 is sepred specify on the shart is when the shaft is revolved relative to thinkle al. The shoulder 36 is secured to the short 16 by splines 45 so that it can slide immgitudinally, but it is not tree to rotate on the shaft. Finally attached to the lower and or the thinkle is a friction ember, such as how springs 42, a hydraulically estuated friction pad, or other such device for frictionally empaging with the inside wall of the conjust to secure the thinble against totation with respect to the simit. Frederably, the direction of the shoulder number threads 30s to the come as that of the chaft threads 10s, e.g. righthead throats, and the pitch, or land, of threads 10s to slightly greater than that of threads 30s, with the pitch ratto being above to unity. In this . names, clock-wise respirator of the sheft relative to the thinble sames. shoulder newber 35 to sivenou uppert alightly and a compression load to emerted upwardly on spring almost 37 to usuac buckling. For energie, one retisfantory differential screw was made up using five and one-half threads/inch equare quarters threads/isch square threads on a shoulder approximately 2.5-ductors

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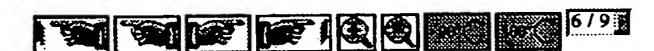


Constant force spring element 31 comprises entired element \$3, advantageously exprinting of a plurality of alongsted solumn disposed around shuft in. Opport bearing plate sender \$4 (a to contact with the apper ends of the entired end is althably positioned on shall in to tremout the force of the spring longitudianity against the bottom and of expendice sender \$4. Lover bearing plate sender \$6 contacts the lover sends of the column and is noted specify along the seaft by landisetimal movement of loter smoulder \$8 or a result of revelving differential senses almost \$9. Grooves \$7 sto provided in seats of the bearing plates, to form an upper same and a lover race, into which the code of the column are inserted. These grooves may be shaped to contact the shape of the column such it samired. A cover \$6 may be employed to amiliate foreign matter from the spring mechanism such to protect the opring.

A needs for limiting the defination of the columns to required. Although the column element functions in a bunkled condition, application of . excessive accurancies look thereto would same total failure or repture of the columns. Therefore, a pair of stops by and I've are provided for this purpose. As shown, the stope are rigidly commerced to the bearing plates, and, in effoot comprise appor and lower limiting slaaves positioned on the shaft to alide longitudinally thereon. The ends of the stops may nove toward, or enay from, each other so the look on the spring number vertes. Lover sleeve aga in prevented from mosing form by lower shoulder 58 assessed to the shaft. 18. Brower, the spacing between the sade is much as to limit the longitudinal travel of the bearing plate masters on they move together to prevent personnt deformation of the online element \$5. Whatons alternative manus for preventing damage to the notions element may also be employed. For example, pins or rings someted on the obert may serve as stops, or the cover 48 provided with suitable commentations may be ampliqued for this purpose to limit longitudical and/or lateral deflection of colome.

The columns of the column clament 43 may be arranged around the smart 16, which as shown here forces a portion of the body of the spring Series, with ends of the columns fitted in the races 57. The solumns may be

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ritted closely together as above, or may be spared around the race, with soperators used botsoon them to meisteds the desired spacing. The runbar of polimon amplitud will dispose upon column characteristics and the ambatain of construction. For example, the stenderness retto of the column may be varied videly, and the column under my be round, flat, first or hinged. The praintred construction is a this, clemes column with tourist sais, free to sow within the races shaped to the surmistre at the soluen ends. Materials which my be satisfuriorily employed for the columns are our ten and low allow simple, throwing and michal-abronius statuless stools, vertous capper been aliene, such 10 as peosphor bronzo, beryllium soppor, the high mickel alloys and other similar materials providing estimactory mechanical properties. Typically, the indivisual columns are or long restaugular cross-section, with the midth bring greater than the laichness, and arranged so that the wider race of the unlumns is normal to the dimester of the sheft. Thus, with surficient compression losding, the columns buckle, and bend shout the axis having the loss's somet of teartia, e.g., outrartly may from the shaft 18.

For example, a group of columns 0.167-inch thick by 0.535-inch wife by 10.626-inches long, with the ends remoted, ware februaried from i.f.S.I.

1360 start, quantied and draws at 575°F. Buth column was found to require a critical sumpression loading of 350 pounds in order to bunkle the solumn.

160, as shown in Figure 3, whereis Fo is the critical bunkling load and points of represents the load and deflection at which the stress in the extress libers of the solumn exceed the yield point of the untertal. Theoretically, the shape of this spring observatoristic curve is described by entres 04'ABO. Actually, this shape this curve is described by OADO due to friction in the system. Potota A and B represent typical screing limits, which, af course, say he varied according to the application for which the spring is designed. For example, where a large number of flexing system are not emissionated, a working stress just below the yield points may be used, while with a great number of flexines, the working stress may be held to less than the enforces limit of the senterial of sonstances are not be actually defined as a started in sonstances and the above-markicoed tease, the latered definition was limited to

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approximately one truck, at which the longitudinal deflortion was approximately 0.825 inches. From more definetion to the maximum deflection, the \$50-pound loading was found to be substantially constant.

columns, each having a critical buckling load of 1250 younds. The interal defination was limited between 0 and about 1.00 inches by expropriately positioning the stope. Once compressional loading the spring element buckled at echetamically 25,000 pounds and from a longitudinal defication of 0.04 inches (markling) to about 0.15 inches the load remained substantially at 25,000 pounds.

Or course, in foreigning a spring element as above it in advantagement to obtain the greatest possible value of longitudinal definition for specified values of laboral deflection and critical bushling load, while unintending the stress level to the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 13 and 2, with multiple flat members unking up such column.

In the operation of the above expending tool for setting a liner in well excised, the mede-up tool to lowered take the sell as mentioned above, with the area 22 in the retreated position. Then the tool is at the desired level, the well tubing is revolved. The friction member is capaçae with the wall of the sening and prevents thinkle it from revolving. With several revolutions of the tubing, lower shoulder 35 is moved agreedly by differential series 39 to bushle spring alarmst 37 which has a predeferminal existing because this last is transmitted agreedly against the lower and of expender 25, and the teperal surface is capaçad with the taperal surface on the tapera of the oran 22 to urgs the terms enteredy with a constantially constant force proportional to the critical buckling load of the spring alament. Subsequently, the expending tool is passed through the lines to expend 10 to the cepting in the meaner described investable force.

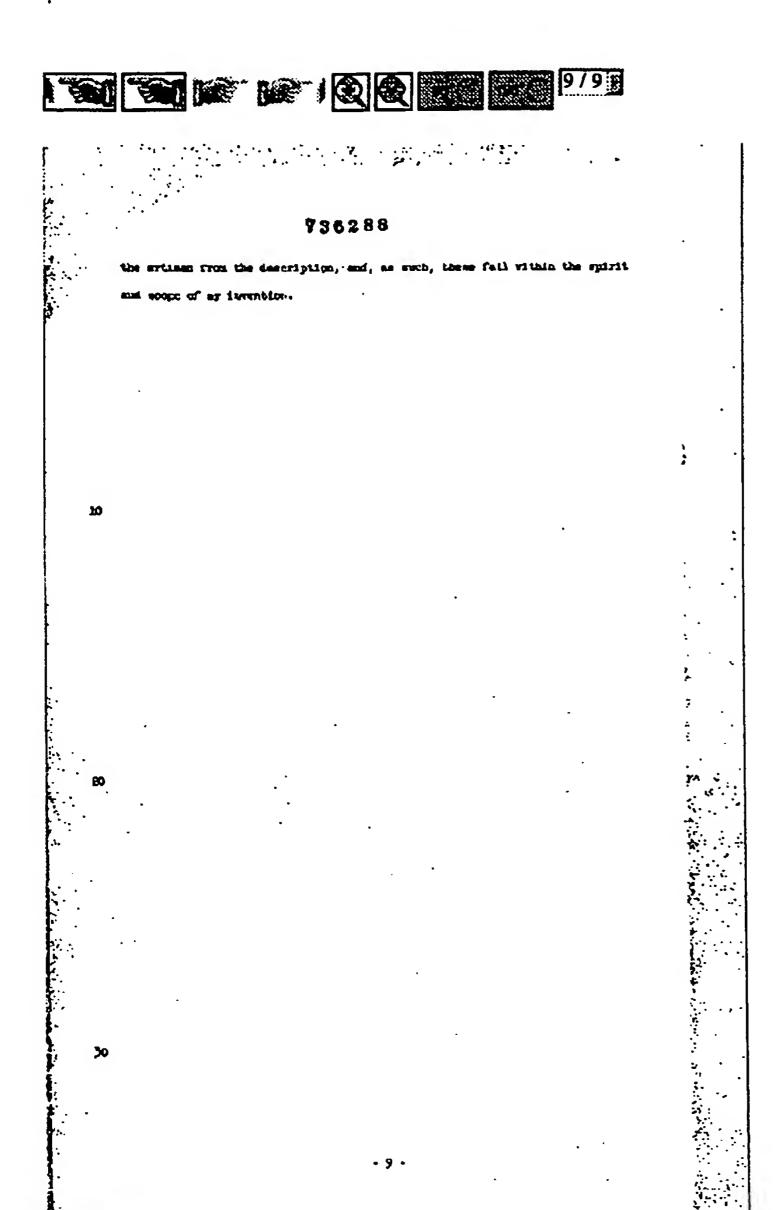
The foregring description of a preferred embalishest of my investion.

Les been gives for the purpose of examplification. It will be understood that

various medifications in the details of exceivantion will become apparent to

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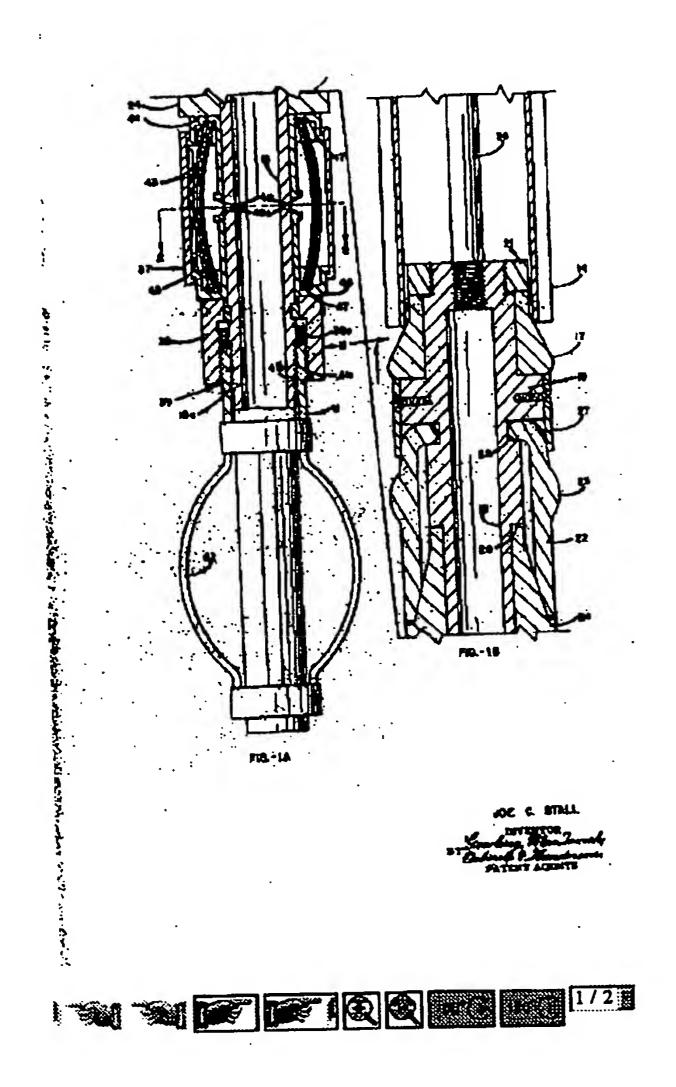


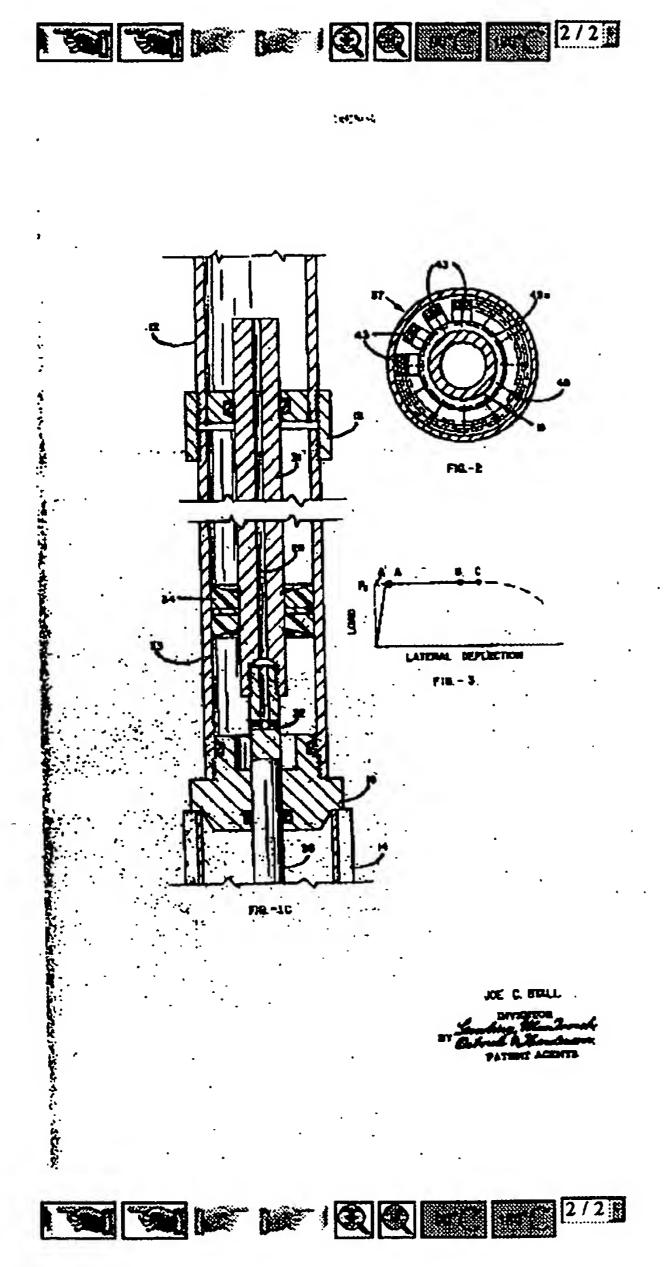


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